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The World Hologram

The Holographic Universe is Everett's Relative State

Andrew Soltau

Abstract: The entity at the heart of Everett's (1957) formulation of quantum mechanics is the state of the memory, defined as the record of observations. He makes clear that this is the sole protagonist of the collapse dynamics. This resolves the problems of quantum theory by demonstrating an ontological dualism: the different types of frame of reference, objective and subjective, are of different logical type.

The structure of information defining the state of the memory is well known to science but invariably assigned a completely prosaic status. This is simply the definition of the perceptual reality: in humans a three-dimensional virtual-reality representation of the world, here the 'world hologram'. The extraordinary status of the world hologram is a function of its multiple instantiation in the unitary wave function. Since the instantiations are superposed and coincident the result is a single world hologram – of which the effective physical environment is the superposition of all these worlds: a 'class-of-worlds-as-a-world'. This domain is determinate solely where observed: all else is the superposed sum of all possible physical variations. The two different types of frame of reference exist at two different levels of logical type. This is the missing lexicon. The paradoxical effect of observation in quantum mechanics is an emergent, second-logical-type phenomenon.

This type of world is precisely described by the holographic principle. In each one, physical determinacy is defined on the boundary of perception: the cosmological horizon in this frame of reference. The holographic universe is not the absolute reality but simply the effective physical environment of the protagonist, Everett's relative state. It is idiosyncratic to the individual. This gives rise to the many worlds on the basis defined in Lockwood's (1989) many-minds formulation. In each one the world hologram is the ontological basis of the physical reality of the protagonist, the conscious individual.

1 The Inside View

A fundamental requirement of physics is objectivity, but as Mermin explains it is the exclusion of the perceiving subject, the protagonist of life, that has produced the great paradoxes:

> ... the perceiving subject has as important a role to play in understanding the nature of physical science as does the perceived object. (2014)

This is crucial because the frame of reference of the perceiving subject is not the same thing as the objective physical frame of reference naturally assumed in the modern paradigm, the quasi-classical world. There is an ontological dualism that has been invisible. It is clear that there are two very different types of frame of reference in the new physics but the full significance has been elusive:

> … the development of relativity theory and quantum mechanics has taught us that we must carefully distinguish between two different views of a mathematical structure:
>
> - The *bird perspective* or *outside view*, which is the way a mathematician views it.
> - The *frog perspective* or *inside view*, which is the way it is perceived by a SAS [self-aware substructure] in it.
>
> (Tegmark, 1998, p. 23; emphasis in original)

As he describes, the outside view follows the linear dynamics, so this defines all possible physical worlds:

> There is only one wavefunction, and it evolves smoothly and deterministically over time without any kind of splitting or parallelism. The abstract quantum world described by this evolving wavefunction contains within it a vast number of classical parallel storylines (“worlds”) … observers perceive only a tiny fraction of this full reality, and they perceive the splitting of classical storylines as quantum randomness. (2007, p. 3)

This is the reality defined by the fundamental math of quantum mechanics, effectively a universe of superposed, decoherent, quasi-classical, physical worlds. On the inside view, however, the individual perceives a specific version of a storyline, and random, specific versions of events are encountered.

This is the essence of Everett's formulation. On the inside view, effectively, there is collapse of the wave function. From the outside-view perspective there is the *appearance* of collapse of the wave function on the inside view.

2 The Measurement Problem

As Everett demonstrates, this resolves the measurement problem. This arises because the two dynamics of quantum mechanics, the linear dynamics of the wave function, and the seemingly inexplicable collapse of the wave function, are fundamentally incompatible. As Barrett states the quantum theory seems inherently flawed:

> … if one supposes that measuring devices are ordinary physical systems just like any other, constructed of fundamental particles interacting in their usual determinate way (and why wouldn't they be?), then the standard theory is logically inconsistent since no system can obey both the deterministic and stochastic dynamics simultaneously. This is the measurement problem. (1999, p. 15)

The view has often been taken that decoherence resolves the measurement problem. As Carroll explains the appearance of collapse is present for any physical observer:

> The Many-Worlds formulation of quantum mechanics removes once and for all any mystery about the measurement process and collapse of the wave function. We don’t need special rules about making an observation: all that happens is that the wave function keeps chugging along in accordance with the Schrödinger equation. And there’s nothing special about what constitutes ‘a measurement’ or ‘an observer’ – a measurement is any interaction that causes a quantum system to become entangled with the environment, creating a branching into separate worlds, and an observer is any system that brings about such an interaction. Consciousness, in particular, has nothing to do with it. The ‘observer’ could be an earthworm, a microscope or a rock. There’s not even anything special about macroscopic systems, other than the fact that they can’t help but interact and become entangled with the environment. The price we pay for such a powerful and simple unification of quantum dynamics is a large number of separate worlds. (2019)

This however cannot be the complete answer. As Bacciagaluppi states, though it has been claimed that “decoherence provides the complete answer:

> As pointed out by many authors, however (recently e.g., Adler 2003; Zeh 1995, pp. 14-15), this claim is not tenable.

The preferred basis problem remains unresolved. This is the question of on what basis exactly reality is defined. Here there is recent new evidence.

3 The Preferred Basis

The paradox of Wigner's friend shows that physical reality must be different for different observers. In this case the basis on which it is defined cannot be simply the conventional quasi-classical world. Exactly this kind of observer-dependent situation has been confirmed in recent experimental research by Proietti et al.:

> This result lends considerable strength to interpretations of quantum theory already set in an observer-dependent framework and demands for revision of those which are not. (abs, 2019)

So the experimental evidence confirms the dictum of QBism:

> This means that reality differs from one agent to another. This is not as strange as it may sound. What is real for an agent rests entirely on what that agent experiences, and different agents have different experiences. (Fuchs et al., 2013, p. 3)

In other words, each individual protagonist exists in a different version of the world, defined by a different quantum state: a different 'quantum-mechanical frame of reference'. Thus the preferred basis must be of this nature.

If the basis adopted by Lockwood is adopted the question is readily resolved. Here the price is the non-physical nature of the inside view, as specifically invoked in Everett's formulation, but this inherently resolves the preferred basis problem. As Barrett states:

> Making the total angular momentum of all the sheep in Austria determinate by choosing such a preferred basis to tell us when worlds split, would presumably do little to account for the determinate memory I have concerning what I just typed. But this is the problem, we do not really know what basis would make our most immediately accessible physical records, those records that determine our experiences and beliefs, determinate in every world. (1998)

In Lockwood's formulation the record of observations *is* the basis, but this directly contradicts the current paradigm. As Tegmark states:

> Decoherence also explains why states resembling classical physics have special status: they are the most robust to decoherence. (2007, p. 2)

The resolution is a dualism of bases, both ontological in that frame of reference. The price is that the record of observations defines the determinacy of the effective physical environment, a seeming oxymoron.

4 The World Hologram

The first step to in the explanation is the full description of the nature of the inside view for human observers, which seems to have been greatly overlooked. The inside view is defined by the record of observations. The record of observations is the state of the memory in Everett's formulation, the core component of the theory. As he states it is “Judged by the state of the memory” (1957, p. 462) that collapse occurs. Hence the record of observations is the protagonist in the collapse dynamics. As he specifically states the body remains in a state of superposition.

Naturally, the inside view defined in this manner is a phenomenon utterly familiar to all conscious individuals. This is the definition of the perceptual reality, meaning the field of information that is directly and immediately experienced. The human physiological system produces a virtual-reality representation of the world:

> Our brain constructs a three-dimensional model. It is a virtual reality in the head. (Dawkins, 1998, p. 276)
>
> What we experience directly is a virtual-reality rendering, conveniently generated for us by our unconscious minds from sensory data (Deutsch, 1997, p. 120)
>
> Every last scrap of our external experience is of virtual reality. (Deutsch, 2011, p. 10)

Each observation is the recording of a specific rendering of the immediate environment encountered at that moment. The integrated synthesis of the record of these observations forms the full definition of the virtual reality. This is the known world of this individual: the perceptual reality in its entirety.

As Deutsch goes on to describe, this three-dimensional virtual-reality representation is mentally projected onto the real three-dimensional world so as to match up precisely. This is here called the world hologram: the mentally projected representation of the integrated synthesis of the record of observations, the entire known world of this individual.

This is what is directly experienced. This is literally the inside *view:* a field of information, experienced as reality. This is the three-dimensional, i.e. spatially distributed, representation of the record of observations. This is also the protagonist in Everett's formulation, the individual for whom the textbook cycle of the dynamics of quantum mechanics is a real phenomenon. This is the self-aware substructure. The term individual is here used for such protagonists, and the term observer exclusively for the physical body-mind.

5 World Superposition

The world hologram is multiply instantiated in the many-worlds universe. There is a great number that instantiate a specific world hologram. These worlds are coincident, superimposed, and all are identical to this view. Thus there is only a single world hologram: identical *and* coincident 'copies' of a structure of information cannot be other than a single instance. Thus this is literally the inside view of all of these worlds, superimposed: a 'world superposition'. The net result is a class-of-worlds-as-a-world.

This is the physical reality of the inside view. Effectively, on this view, for the protagonist present in all of them, all the quasi-classical worlds in which it is instantiated are superimposed. Effectively this gives rise to the effect of a quantum superposition, a 'coherent state', rather than a quantum mixture, a 'decoherent state'. This is the nature of the quantum-mechanical frame of reference of the self-aware substructure.

On this inside-view frame of reference, the view directly encountered, the resulting physical reality is determinate solely where observed. Only what has been observed is determinate because only this is the same in all the different versions of the quasi-classical world superposed. Equally, everything not observed is the superposition of all the physically possible ways it could be. Thus the only determinacy is given by the record of observations, the world hologram. In other words, the record of observations defines the determinacy of the effective physical environment of the protagonist.

The class-of-worlds-as-a-world is a second-logical-type phenomenon: it is to the ordinary world of the current ontology as a population is to a person. Consequently it has very different properties. In this domain the making of each observation alters the definition of the world hologram, and thereby changes the definition of the class of worlds that contains it. Thus collapse occurs, *effectively*, on this view. Schrödinger's cat is an ideal example. Before the observation is made, the class-of-worlds-as-a-world of the experimenter contains all possible versions of the unobserved outcome. Afterwards, only those worlds in which that specific outcome occurred are included in the world superposition.

Effectively, therefore, on the inside view, the quantum state of the environment operates exactly as described in the Copenhagen interpretation, and more recently Quantum Bayesianism. Only the observed, the experienced, is real. This, however, does not do away with the world 'out there', the 'actual' physical reality that gets observed. This is just the nature of the other type of physical reality, a World, a world of inside-view physics. *This* frame of reference follows the standard von Neumann-Dirac formulation of quantum mechanics just as Everett declares.

6 Ontological Dualism

The missing piece of the quantum puzzle is the dualism of ontologically fundamental domains. The quasi-classical world is ontic as is obvious, but the class-of-worlds-as-a-world is ontic also, on the inside view. On the inside view the determinacy of the domain is defined by the world hologram, and changes as the definition of the world hologram changes when an observation is made. Thus there is a relative onticity. As stated by Atmanspacher et al.:

> The central point of the concept of relative onticity is that states and properties of a system, which belong to an epistemic description in a particular domain, can be considered as ontic from the perspective of another domain. (2005, 19)

The seemingly inexplicable measurement problem is the result of relative onticity applying both ways. In other words, the inside and outside views of physical reality are unilaterally ontic. They operate at different levels of logical type, hence the fundamental dualism.

7 The Real Person

On the inside view, in the class-of-worlds-as-a-world, the principle of world superposition inevitably applies to the body itself. Only what is observed is real and determinate. Thus even the body housing the protagonist, the observer, is indeterminate except where defined in the world hologram. In other words, the world hologram is not only the protagonist in technical terms, Everett's record of observations, it is also the real person 'in here'.

The indeterminate nature of the body of the observer is an inevitable consequence of this type of physical reality. This does not of course mean that the individual is just a field of information and does not really have a body. Each individual is present in a vast number of bodies simultaneously: a class-of-bodies-as-a-body. Effectively, therefore, the individual is a real physical entity, but determinate solely where observed. The determinacy of the real person, the self-aware substructure, is entirely defined by the world hologram.

This provides a simple rationale for the seemingly ephemeral nature of the individual protagonist. As von Baeyer states in QBism:

> If I am the agent, the objective world is everything outside my mind—including other agents and even my own body. All of that I

> may, if I chose, treat quantum mechanically and describe by wave-functions. (2016, p. 154)

He is defining the mind here as “... my own experiences and perceptions” i.e. the world hologram. In other words, the world hologram, Everett's record of observations, is the whole of the real person, a protagonist of life. This is the mind in Lockwood's formulation. This is the definition of the conscious individual.

8 The Self-Concept Avatar Figure

Instinctively this seems highly inadequate as the full definition of the real person, but this is precisely the same thing as that defined by the self-concept. Here again the relevant structure of information is highly familiar, but accorded an entirely mundane meaning. The self-concept is the sum of the things one knows about oneself, the complete mental image produced over time. This is the integrated synthesis of all the observations of oneself. This forms the self-concept avatar figure, the central element of the world hologram. This is how the protagonist is represented in real time in the perceptual reality, as the holographic representation of the body at the centre of the world hologram.

As with the rest of the world hologram, the self-concept is projected precisely onto that which it represents: the three-dimensional physical reality. As Deutsch states:

> Consider the nerve signals reaching our brains from our sense organs. Far from providing direct or untainted access to reality, even they themselves are never experienced for what they really are – namely crackles of electrical activity. Nor, for the most part, do we experience them as being *where* they really are – inside our brains. Instead, we place them in the reality beyond. We do not just see blue: we see a blue sky up there, far away. We do not just feel pain: we experience a headache, or a stomach ache. The brain attaches those interpretations – 'head', 'stomach' and 'up there' – to events that are in fact within the brain itself. (2011, p. 10)

In other words, the direct experience of the body is actually the experience of the self-concept avatar figure at the centre of the world hologram.

In Everett the self-concept appears as the record of machine configuration. He defines the observer as a machine, a recording device, that records: “... sensory data and machine configurations” (1957, p. 457). The integrated synthesis of the record of observations of sensory observation of the world gives rise to the world hologram. The integrated synthesis of the record of observations of machine

configuration, in humans the body-mind of the observer, gives rise to the three-dimensional self-concept avatar figure. Just as the world hologram is the known world, this is the known self.

Given that the body is indeterminate except where observed, the self-concept avatar figure is the sole definition of the individual on the inside view. So this is the real person in ordinary terms because everything not defined in the self-concept avatar figure is indeterminate. This is the individual, the protagonist on the inside view, in contrast to the observer, a physical entity.

How can this be the real person? What about the mind? The mind is here defined as an attribute of the physical body, the computational and management capability, the operating system of the hardware of the the neural network. On this definition the mind is part of the objective world in von Baeyer's statement. Thus in the class-of-worlds-as-a-world it is indeterminate: just as the effective physical body is the superposed sum of all possible bodies instantiating this world hologram, the effective mind is all possible minds instantiating this world hologram.[1]

The known self, the self-concept avatar figure, is the reality of the individual on the inside view. The actual protagonist, however, is the whole of the world hologram: the remainder is the unconscious. All together this constitutes the real person in the world, psychologically and physically.

9 The Unconscious

There is a crucial operational distinction between two attributes of the protagonist, conscious and unconscious. The conscious is the immediate awareness of experience. This is the sensorium, the view of reality that is currently being perceived at each moment, and added to the record of observations. This is is the definition of conscious awareness: the field of information directly and immediately experienced. The rest of the world hologram is the 'personal unconscious', meaning those attributes of the mind that are accessible, but not in immediate conscious awareness. This is Jung's (1969) classification.

The mind external to the world hologram defines another phenomenon in search of an explanation, the collective unconscious. This Jung defines as generic to all humans:

1 Remarkably this means that the mind of the individual is logically of the same type as a quantum computer, operating all possible mental states and computations at the same time. Creativity needs no further explanation.

> The collective unconscious is a part of the psyche, which can be negatively distinguished from a personal unconscious by the fact that it does not, like the latter, owe its existence to personal experience and consequently is not a personal acquisition. … This collective unconscious does not develop individually but is inherited. It consists of pre-existent forms, the archetypes, which can only become conscious secondarily and which give definite form to certain psychic contents. (1969, p. 43)

This is all part of the operating system, developed over evolutionary periods of time. It is not under conscious control. It is a fundamental component of what makes up complex human cultures. The fascinating component of the concept is that this exists across the boundaries of individuals' identities in a dynamic manner, thus providing a rationale for the remarkable type of properties described by Jung (1969, p. 43). The human being embodies distinct cybernetic layers, some collective, in a manner that has not been generally recognised.

This defines the major components of the psyche in operational terms. The ego is the identification with the sensorium and the self-concept avatar figure. The world hologram as a whole is a different type of entity to the physical body-mind and its limited self-identity. The unconscious defines the known world, and this is the major part of the psyche. The world hologram as a whole is the 'higher self' referred to in traditional spiritual practice.

10 The Functional Identity

Psychological habituation takes for granted that the known world is 'the world', and the self-identity is 'me'. On the inside view both are literally correct in terms of what is actual and determinate in the frame of reference directly encountered. In this domain the world hologram is the real person, the protagonist of life. This is the protagonist in Tegmark's description, the self-aware substructure. Objectively this seems like a vital but very minor property of the self as usually conceived, the whole trillion cell physical entity with its sophisticated and complex neural system. The world hologram, however, is the real person 'in here' because this is the whole of the 'functional identity' of the individual. As Everett states, referring to the physical observer as the machine:

> … the actions of the machine at a given instant can be regarded as a function of the memory contents only, and all relevant experience of the machine is contained in the memory (1957, p. 457)

In other words, every aspect of the decision-making capability of the observer is

contained in the memory, defined as the record of observations. Thus the world hologram defines both the functional identity in operation and the determinacy of the body-mind. This is the real person. This 'resides' in the body, but this is both what one knows oneself to be, and the complete definition of the determinacy of the operational self.

11 The Missing Subject

Naturally, it is a fundamental tenet of physics that subjective effects should be ruled out, but as Mermin (2014) describes it is the omission of the perceiving subject from the science that is the source of the great paradoxes:

> In *Nature and the Greeks*, Austrian physicist Erwin Schrödinger traced the removal of the subject from science back more than two millennia. Alongside the spectacular success of physical science, this exclusion of personal experience has given rise to some vexing and persistent puzzles and paradoxes. Two such unrelated long-standing problems are both resolved by recognizing that the perceiving subject has as important a role to play in understanding the nature of physical science as does the perceived object. The first problem is the notorious disagreement, confusion and murkiness that for almost a century has plagued the foundations of quantum mechanics, in spite of the theory's extraordinary usefulness and power. The second, less famous, problem has been with us at least as long: there seems to be nothing in physics that singles out 'the present moment'. Albert Einstein called this the problem of 'the Now'. Both problems are symptoms of the exclusion from physical science of the perceiving subject, and are solved by restoring what the ancient Greeks removed. (2014)

This omission produces a physics with a precisely world-hologram-shaped hole. As Wilczek describes, the vital "observer" is missing from the science:

> The relevant literature [on the meaning of quantum theory] is famously contentious and obscure. I believe it will remain so until someone constructs, within the formalism of quantum mechanics, an "observer," that is, a model entity whose states correspond to a recognizable caricature of conscious awareness, and demonstrates that the perceived interaction of this entity with the physical world, following the equations of quantum theory, accords with our experience. That is a formidable project, extending well beyond what is conventionally considered physics.

> Like most working physicists, I assume, perhaps naively, that this project can be accomplished, and that the equations will survive its completion unscathed. In any case, only after its completion might one legitimately claim that quantum theory is defined by the equations of quantum theory. (2006, p. 142)

The world hologram is literally the definition of the terms he defines. As has been described, the world hologram is the *definition* of conscious awareness: it is the perceptual reality itself. There is also no question that the interactions of this entity with the environment follow the equations of quantum theory precisely. That is the basic tenet of Everett's formulation. As he states:

> … we shall deduce the probabilistic assertions of Process 1 as subjective appearances to such observers, thus placing the theory in correspondence with experience. (1973, p. 9)

In other words, the world hologram *is* the "observer", the entity to which collapse is real. This is the missing protagonist of the quantum dynamics.

The nature of this "observer" is certainly confusing. It is a field of information. It is the reality directly experienced, the perceptual reality. And according to Everett it is both the protagonist of the dynamics and also the functional identity of the individual. At the same time it defines the determinacy of the physical environment. The reason is that the worlds in the class-of-worlds-as-a-world are selected on the basis of the world hologram.

12 Multisolipsism

As described in Wigner's friend (1961) and new confirmed by Proietti et al. above, each individual protagonist exists in a different quantum-mechanical frame of reference. As in each such domain the effective physical environment is defined solely by the world hologram, the mind in the many-minds theory of Lockwood, this is a real solipsism. As Everett (1973, p. 6) states, solipsism is entirely in accord with the facts of quantum mechanics.

As QBism demonstrates, the world determinate solely where experienced by each protagonist individually:

> ... removes the paradoxes, conundra, and pseudo-problems that have plagued quantum foundations for the past nine decades. (Fuchs et al., 2013, p. 1)

It works, but this is very different to the original concept of solipsism. This does not mean that other people are not real. Other individuals encountered in the world

are all perfectly real, but they live in personal, physical, parallel realities with different definitions, and different likely futures defined by different Bayesian probabilistics. The implied ontology is a multisolipsism.

The solipsisms are coexistent. They share common ground. Naturally, these realities can often be the same with regard to the current location. With respect to two individuals standing next to each other and making essentially the same observations, their physical realities are of course the same – with regard to this environment at the present moment. This is the nature of each individual quantum-mechanical frame of reference. All the parallel realities exist in a non-exclusive, overlapping manner, each with an idiosyncratic definition of physical reality.

13 The Holographic Universe

The physical reality of the protagonist provides a simple intuitive explanation of the holographic principle of t'Hooft (1993). This holds that the universe is like a gigantic hologram, defined solely on the surface of its boundary. As stated by Smolin this is a consequence of the second law of dynamics. As he comments:

> … for the first time in the history of quantum gravity we have in our hands an idea which at first seems too crazy to be true, but which survives all our attempts to disprove it. (2000, p. 178)

It is only too crazy to be true when applied to the quasi-classical world of the current paradigm. Taken as a description of the effective physical environment defined solely by observations, the class-of-worlds-as-a-world, this is the natural definition. The world hologram, the record of observations, is the definition of the surface of the boundary of the world of the protagonist, and it defines the determinacy of this world.

Everett's relative state is the state of the system defined by the correlations established by observations. In other words the holographic principle defines the same physical environment for the protagonist as Everett's many-worlds theory.

As Smolin (2000, p. 174) also states, according to the second law of dynamics there can be no more definition to the region beyond the interface than defined by the interface itself. Applied to the objective physical world this sounds truly crazy, but on the inside view this is the case in a very natural manner. The world hologram is literally the interface to the rest of the universe; and by definition everything beyond this interface is indeterminate in this frame of reference.

The holographic principle seems to mean that the volume of space is illusory, but no such drastic remodelling of common sense is required. The principle describes the physical reality of each protagonist. The volume of space-time is

perfectly real, manifesting the plurality of decoherent quasi-classical worlds defined by the unitary wave function. As Smolin goes on to say:

> … it is not enough to say that the world is a hologram. The world must be a network of holograms (p. 178)

14 Transtemporal Reality

In order to complete the explanation of the operational system of physics a third level of logical type is required. This explains the origin of the transtemporal nature of the world encountered. It also explains how the conscious individual can be both the determinant of the world and the knower of the world.

All conscious individuals experience the passage of time, thus a transtemporal reality, but in both relativity and quantum theory the universe is static, unchanging. Time cannot actually pass. That is an oxymoron. The only possible explanation is that a succession of states of the world is encountered in sequence. As Weyl states:

> The objective world simply *is*, it does not *happen*. Only to the gaze of my consciousness, crawling upward along the life line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time. (1949, p. 116: emphasis in original)

In other words, the frame of reference of consciousness crawls upward along the four-dimensional space-time worldline, and thus there is the experience of a succession of states of the world hologram. Just as there is the appearance of collapse of the wavefunction in quantum theory, there is the appearance of the passage of time in the relativistic block universe.

The logical types in the operational system are the same as a movie system. The frames are of the first, primitive logical type. The movie, the set of frames, is of the second. The iterator is of a third logical type, operational on all movies, the set of all sets of frames. It is universal to the system. Similarly, the moments in time, events along the worldline, are first-logical-type phenomena. The sequence is like the movie film, second-logical-type. The moving frame of reference is third-logical-type.

The problem is that such a phenomenon cannot exist in the physics as currently defined; but that is the whole point. As Weyl declared: “... the consciousness in this function does not belong to the world” (1934, p. 1). This is confirmed by Chalmers, who proposes that the experiencing phenomenon can only be: “... a

fundamental feature of the world, alongside mass, charge, and space-time." (1995, p. 216). This answers Hawking's famous question: "What is it that breathes fire into the equations?" (1988, p. 174)

On the inside view, in the moving frame of reference, the static block universe operates exactly like a DVD in action that produces the effect of the movie. As Tegmark states: "So life is like a movie, and space-time is like the DVD" (Kuhn, 2015). The fleeting image in space is the effective time-evolution of the world hologram, as the moving frame of reference passes from moment to moment along the worldline of the body. Effectively time passes, in experience. The gaze is the Now, the present moment that Einstein (Carnap, 1963, p. 37) specifically identifies as an impossibility in the physics.

Transtemporal reality is literally the movie of life, the moving picture of the world hologram experienced by consciousness. This is Weyl's fleeting image in space which continuously changes in time. The known world is the memory, the recorded history that defines the Bayesian future. The Now, the present moment constantly moving into the future, is the moving frame of reference of the fundamental consciousness. This is the inescapable requirement for an effectively transtemporal world in the static block universe. The system effectively operates with the movement of the frame of reference, a third-logical-type phenomenon.

This experiencing consciousness is the *I* in each reality. The self-concept avatar figure is the *me*. The body is the structure. Thus the perceiving subject in the fullest sense is ontologically triune. This is how the conscious individual can be both the definition of the world and the knower of the world. The world hologram is the definition, the known. The knower is the third-logical-type phenomenon. This, the subjective attribute of the conscious individual, is what solves the second of the problems that Mermin points out are resolved by the perceiving subject, the present moment, the Now.

The first problem, the paradox that has plagued the foundations of quantum mechanics, is solved by the second-logical-type phenomenon of the world superposition. The second problem is solved by the third-logical-type phenomenon of consciousness.

15 Conclusion

As Everett demonstrates, the protagonist of the collapse dynamics is the state of the memory, defined as the record of observations, here the world hologram. It is solely "Judged by the state of the memory" (ibid) that the dynamics operates. This is the subjective reality, the inside view of the world. This field of

information is the known world of this individual. It is multiply instantiated in the universe of the unitary wave function, and as a result the physical reality of each inside view is a class-of-worlds-as-a-world, a second-logical-type phenomenon.

This field of information is intensely familiar to every conscious individual: the integrated synthesis of the record of observations forms the perceptual reality, the three-dimensional virtual-reality representation of the world experienced at every moment: here the world hologram. Mentally projected to coincide precisely with the physical environment this is the known world.

The perceptual reality is both Everett's protagonist and the definition of the determinacy of the effective physical environment, the world. This is the bit that seems to make no sense. How can a structure of information define the physical reality? The resolution is that the physical frame of reference of this protagonist is not the quasi-classical world of the current paradigm, but the superposed sum of all such worlds in which it is instantiated, a class-of-worlds-as-a-world. This is defined by the record of observations solely as a result of the elements of the class being 'selected' by containing the world hologram.

A second-logical-type phenomenon, this has different properties. Observation alters the definition of the class, and thus the determinacy of this effective physical environment of this protagonist.

The missing piece of the quantum puzzle is an essential dualism: fundamental ontologies at different levels of logical type. The deep paradox of quantum theory arises because the two are conflated. As Russell (1901) demonstrates, failure to discriminate between different logical types inevitably leads to paradox and nonsense results. In quantum theory the incompatible dynamics are operating at different levels of logical type. The linear dynamics operates in the context of the quasi-classical world: the basis is that of classical physics. The collapse dynamics operates in the context of the class-of-worlds-as-a-world: the basis is the observations recorded that define the correlations with these worlds.

The virtual collapse dynamics is what Everett describes. On the outside view there is the appearance of collapse, on the inside view. *On* the inside view, the physical frame of reference of the protagonist changes with the making of each observation, and the result is the determinacy of the specific outcome observed. In this quantum-mechanical frame of reference the events recorded as sensory data have determinately happened, in this idiosyncratic physical frame of reference. All else is indeterminate because all else is the superposition of all possible versions of physical existence.

Effectively, on the inside view, the collapse of the wave function is a real phenomenon. This is the *nature* of the inside view: it is defined by a field of information, and its definition alters as the field of information alters.

This explains the relational nature of Everett's relative state. The physical reality of each individual is idiosyncratic: each has a different quantum-mechanical frame of reference and a different Bayesian probabilistic defining the future.

Each such domain is a 'holographic universe' of the form proposed by t'Hooft (1993). Because only what is observed is determinate, the determinacy of the physical reality is defined solely on the observed surface of the environment, the cosmological horizon in this frame of reference. The world hologram is of course the size of the cosmos, but defined solely on the observed surface.

This resolves the philosophical problem of the holographic principle. The concept of the holographic universe seems to mandate that the volume of the universe is illusory, but this is not required to fit the logic of the concept. It is just the determinacy of the effective physical reality of the perceiving subject that is defined solely on the lower-dimensional boundary of the region.

This is a second-logical-type phenomenon: the holographic universe is the inside-view universe. The ordinary, objective physical-reality universe, the domain of the decoherent quasi-classical world, is fully real. Space-time is all 'there'.

The holographic principle defines exactly the topological form of Everett's formulation where the physical reality is defined by observations. As Bousso explains:

> ... for physics to make sense, you must restrict your description of the universe to what a single observer can see. (Gefter, 2010)

As Everett states, a solipsism fits the facts of quantum mechanics perfectly. As has been shown, the physical frame of reference of each individual is idiosyncratic: the class of quasi-classical worlds. Because the different versions of the class naturally overlap and intersect, the result is interacting, overlapping, holographically-defined worlds in action.

At the first, primitive level of logical type Everett's no-collapse universe is all possible decoherent quasi-classical worlds. At the second level it is all possible versions of a class-of-worlds-as-a-world, each one determinate solely where experienced, effectively a solipsism. At this level of logical type the universe is system of non-exclusive solipsisms, the worlds of many minds, many world holograms: realities different for different agents as described in QBism (Fuchs et al., 2013). This is exactly the type of environment Smolin sees as directly required by quantum gravity. As he states:

> … it is not enough to say that the world is a hologram. The world must be a network of holograms … the holographic principle is the ultimate realization of the notion that the world is a network of

> relationships. Those relationships are revealed by this new principle to involve nothing but information. (2000, p. 178)

On the inside view the universe is a network of fields of information, world holograms, each one the protagonist in an idiosyncratic physical frame of reference, the determinacy defined by the world hologram, the definition of the boundary of that domain.

Since the world hologram, Everett's state of the memory, is the definition of the determinacy in the physical frame of reference encountered, this field of information is the fundamental component of the inside-view reality.

This is what has made the solution to the quantum paradoxes invisible. There is an ontological dualism. Not exactly between mind and body but between the physical reality of the subjective inside view and the objective physical reality of the outside view. As Wheeler stated:

> ... it is not unreasonable to imagine that information sits at the core of physics. (1998, p. 340)

On the inside view this is fully correct. The subjective, inside view is primal, ontologically fundamental in that frame of reference. Collapse operates on observation. Schrödinger's cat and Wigner's friend are retrodicted. The strange result is that the protagonist is the same thing as the known world, with the known self at the centre, and this is the sole definition of the determinacy of the real physical world in this frame of reference. Conscious individuals are holographic universes.

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